VETIVER IN INDIA: HISTORICAL PERSPECTIVE AND PROSPECTIVE FOR DEVELOPMENT OF SPECIFIC GENOTYPES FOR ENVIRONMENTAL OR INDUSTRIAL APPLICATION

U.C. Lavania
Central Institute of Medicinal and Aromatic Plants, Lucknow 226015, India
Email:<lavaniauc@yahoo.co.in>

ABSTRACT

Vetiver is native to India, and has been in traditional use since ancient times for its perfumery oil obtained from roots. Also its hedges have been applied for contour protection since centuries. However, planned efforts to rehabilitate usar soils using vetiver plantations and organic soil amendments were initiated in 1956 by the National Botanical Garden, Lucknow (a national lab of CSIR, now known as National Botanical Research Institute) that showed that vetiver grass has exceptional ability to withstand extreme sodicity and alkalinity, could help improve soil fertility and facilitate ground water recharge. Scattered efforts have since been made to apply vetiver plantation in soil reclamation and conservation with the support of state governments in various parts of India. The World Bank initiated several projects in India in 1980s for systematic development of Vetiver Grass Technology (VGT), now popularly known as Vetiver System (VS) for watershed management, soil conservation and slope stabilization. However, in its homeland vetiver still remains the choice of industrialists for its valuable root oil, despite having potential for development of technologies for its multifarious applications.

Vetiver is found occurring in India in wild state throughout tropical and sub-tropical plains, particularly along the riverbanks and over marshy lands. It has wide range of ecological distribution ranging from sandy seacoasts and swamps to plains and foothills, and also on the hilltops up to elevations of 800m in the Kumaun hills of Uttar Pradesh. Based on geographical distribution patterns and detailed chromosomal evolutionary parameters it is suggested that south Indian peninsula is the area of its primary center of origin from where it has diverged in two directions: (i) towards the north in the warm and dry northwest and the warm and humid east- central Indian plains, and (ii) towards south-east Asia and other parts of the world. Vetiver cultivars found outside south-east Asia are supposedly of south Indian origin having non / low seed-setting characteristics.

Two distinct morphological complexes of vetiver are found to inhabit spatially separated geographic regions in India: one in the north along the Indo-gangetic plains and adjoining areas mainly in the states of Rajasthan, Madhya Pradesh, Uttar Pradesh and Bihar, and the other in the south along the east and west coasts of Indian peninsula in the states of Andhra Pradesh, Kanataka, Tamilnadu and Kerala. The two races are distinctly different. The north Indian wild types are profuse flowering high seed-setting having *narrow* leaves producing superior quality of laevorotatory root oil (ruh-khus or khus oil) and south Indian cultivated types are low / late flowering, low/non seed-setting with *wider* leaves producing lower quality of dextrorotatory root oil (vetiver oil). Extensive work on evaluation of genetic diversity, genetic analysis, genetic improvement has been done on Indian vetiver at the Indian Agricultural. Research Institute, New Delhi, National Bureau of Plant Genetic Resources, New Delhi, Central Institute of Medicinal and Aromatic Plants, Lucknow, CS Azad University of Agriculture and Technology, Kanpur, and Kerala Agricultural University's research station at Oddakali. A good number of superior clones, north-south hybrids, artificial polyploids have been isolated for high productivity of essential oil and high value perfumery notes ranging from earthy-to-rosy-to- saffron odour. Depending upon the oil

quality and free vetiverols, there could be a price difference of four fold between laevorotatory and dextrorotatory oils.

As stated above Vetiver has two distinct applications: (i) for its root essential oil for perfumery industry for which we need genotypes that produce high concentration and superior quality of essential oil in their roots, and (ii) for multifarious environmental applications, including mitigation of carbon emissions for which we need plant types that produce (a) low oil / virtually no oil in its roots that works as a deterrent to local root diggers, (b) fast growing ideal root physiography suiting to desired application.

With tremendous progress made in applications of Vetiver System ecotechnology, it is high time that due emphasis is laid on the development of designer genotypes suiting to specific applications. Also, it is desirable that no-dig cultural practices are standardized if roots are to be harvested for essential oil to avoid soil carbon loss and carbon recycling to atmosphere. India being the home of vetiver is the only country where profuse seed formation takes place in its natural habitats. Seed grown progenies offer huge opportunities to tap vetiver diversity to isolate plant genotypes suiting to specific applications. The genotypes so selected could be made to have noninvasive features with no seed formation to meet international obligations by changing them into triploids through tetraploidy. Efforts in this direction are under way in author's laboratory.

Keywords. Vetiver, History, Origin and Distribution, Morphological Diversity, Genetic Diversity, Polyploidy, Designer genotypes, Non-invasiveness

1. INTRODUCTION

The name “vetiver” is derived from the Tamil word “vettiver”. It is called “vetivert” in Reunion Island where it is naturalized and is said to have been introduced from India through Indonesia. Vetiver is known to be in use in India both for its fragrant oil and as traditional medicine since antiquity (Husain *et al.* 1984, Husain 1994), and its hedges have been applied for contour protection in India since centuries (National Research Council, 1993). Multifarious uses of this plant are on record in ancient Ayurvedic treatises by Charak, Bagbhananda and others (Masood 1958). Two ancient Sanskrit manuscripts, Surapala’s Vrikshayurveda (c. AD 1000) and Chakrapani Mishra’s Vishvavallabha (AD 1577) refer to the use of vetiver along with other herbals stating that putting the powder of *ushira* (Sanskrit name for khus roots) in wells and other water reservoirs, the turbid, bitter or foul smelling water can be turned into tasty, clean and sweet smelling water (cf. Nene 2004). Authors of *Pharmacographica Indica* vol. III, 572; *Indian Oil Soap J.* 1948, 13:138 reported inscriptions as *Turushkadanda* on copper plates dating as back as 1103 AD found in Etawah (Uttar Pradesh) listing *Khus* perfume as Royal articles and levy of duty on “Khus Oil” under use by the King of Kannauj (Shukla 1957, Virmani and Datta 1975). In recent past there was a special “Bharatpur Khus Act, 1942” in ex-Bharatpur state which controlled the processing of vetiver through licensing system (cf. Virmani and Datta 1975). All this indicates that the Indians were the first to recognize vetiver for its aromatic and medicinal uses, followed by its other cottage and environmental uses in India and elsewhere (Lavania 2002, 2003a, 2003b, Lavania and Lavania 2000, Lavania *et al.* 2004).

2. OCCURRENCE, GENETIC DIVERSITY AND CULTIVATION

Vetiver is found occurring in India in wild state throughout tropical and sub-tropical plains, particularly along the riverbanks and over marshy lands. It has wide range of ecological distribution ranging from sandy seacoasts and swamps to plains and foothills, and also on the hilltops up to elevations of 800m in the Kumaun hills of Uttar Pradesh (Gupta and Pareek 1995, Lavania 2002). Two distinct morphological complexes of vetiver are found to inhabit spatially separated geographic regions in India: one in the north along the Indo-gangetic plains and adjoining areas mainly in the states of Rajasthan, Madhya Pradesh, Uttar Pradesh and Bihar, and the other in the south along the east and west coasts of Indian peninsula in the states of Andhra Pradesh, Karnataka, Tamilnadu and Kerala. The two races are distinctly different. The north Indian wild types represented by "Bharatpur type" are profuse flowering high seed-setting having *narrow* leaves with vigorous roots producing low concentration superior quality laevorotatory root oil (ruh-khus or khus oil) and the south Indian "cultivated type" that are late and low flowering with high pollen sterility and non seed-setting with *wider* leaves producing low quality dextrorotatory root oil (vetiver oil) resembling Java vetiver (Guenther 1972, Gupta and Pareek 1995). A higher order of genetic diversity with respect to ecological / geographic adaptation, morphometric traits, reproductive behaviour and essential oil concentration and composition is found in the Indian subcontinent, followed by Indonesia (Lal *et al.* 1997, Lal 2000, Lal and Sharma 2000).

Whereas roots collected from wild occurring in north Indian states of Rajasthan and Uttar Pradesh have been in traditional economic usage, but systematic cultivation of vetiver has been in practice in south India, mainly in Kerala (Thiruvambadi, Neyatunkara), Andhra Pradesh (East Godavary and Kurnool), Tamilnadu (Mettupalayam, Nilgiri and Coimbtore) and in small areas of Karnataka state. Remunerative cultivation of south Indian vetiver was established during 1940s under the auspices of the Kerala Soap Institute, Kozikode. In 1980s M/S Encee Aromatics Ltd., Mettupalayam took-up cultivation of vetiver under irrigated conditions in Coimbatore and Periyar districts in plains, and Cinchona Department of Tamilnadu in Nilgiri hills (cf. Husain *et al.* 1984). Extensive collections made from natural habitats in north India have been subjected to genetic analysis and performance evaluation of their clonal and seed progenies and hybridization with south Indian types conducted at the Indian Agricultural. Research Institute, New Delhi, National Bureau of Plant Genetic Resources, New Delhi, Central Institute of Medicinal and Aromatic Plants, Lucknow, Indore Agriculture College, Indore, Regional Research Laboratory, Bhubaneswar, and CS Azad University of Agriculture and Technology, Kanpur, Harcourt Butler Technical Institute, Kanpur and Kerala Agricultural University's research station at Oddakali. This has led to isolation of several superior clones, north-south hybrids, artificial polyploids for high productivity of essential oil and high value perfumery notes ranging from earthy-to-rosy-to- saffron odour genotypes suitable for commercial cultivation. Further details could be seen elsewhere (Sethi 1982, Husain *et al.* 1984, Sethi *et al.* 1986, Lavania 1988, Lavania 1991, Pareek *et al.* 1992, Gupta and Pareek 1995, Sahoo and Patra 1998, Lal *et al.* 1997, Lal 2000, Lal and Sharma 2000). Depending upon the oil quality and free vetiverols, there could be a price difference of four fold between laevorotatory and dextrorotatory oils. The former mainly available in north Indian vetiver is considered to be superior quality (Lavania 2003a). Necessary cultural practices, including ideal plant density (60 x 40 cms plant to row distance) and crop duration (12 to 15 months for root oil) and mixed cropping systems (with legumes), and oil extraction (hydrodistillation / steam distillation of fresh roots) have been standardized. Mixed cropping systems have been shown to enhance vetiver productivity, optimum utilization of land, water and fertilizer resources, and also in improving soil health. (Gupta and Pareek 1995).

3. ORIGIN AND DISTRIBUTION

In addition to Indian subcontinent, vetiver grows wild in subtropical and tropical areas of world. However, a primitive type of clone that had only male florets compared to the normal occurrence of hermaphrodite flowers has been reported from wild population in south India (Kumar 1963). Occurrence of tremendous diversity especially for reproductive features ranging from non-flowering to late-flowering and range of pollen sterility point to the possibility of India being the center of origin. Lavania (1985) made extensive karyomorphological and nuclear DNA estimation analysis on diverse clones of vetiver. Based on geographical distribution patterns and detailed chromosomal evolutionary parameters applied, it was suggested that south Indian peninsula is the area of primary center of origin of vetiver from where it has diverged in two directions: (i) towards the north in the warm and dry northwest and the warm and humid east-central Indian plains, and (ii) towards south-east Asia and other parts of the world. Vetiver cultivars found outside south-east Asia are supposedly of south Indian origin having non / low seed-setting characteristics (Lavania, 1985, 2002)

4. ENVIRONMENTAL APPLICATIONS

Besides essential oil production, vetiver hedges have been applied for contour protection in India since centuries. However, planned efforts to rehabilitate usar soils using vetiver plantations and organic soil amendments were initiated in 1956 by the National Botanical Garden, Lucknow that showed that vetiver grass has exceptional ability to withstand extreme sodicity and alkalinity, could help improve soil fertility and facilitate ground water recharge (National Research Council 1993). Scattered efforts have since been made to apply vetiver plantation in soil reclamation and conservation with the support of state governments in various parts of India.

John Greenfield and Richard Grimshaw introduced vetiver into World Bank assisted projects in India 1980s for watershed management, soil conservation and slope stabilization. That led to systematic development of Vetiver Grass Technology (VGT) now popularly known as Vetiver System (VS). Significance progress is reported on adoption of VS for soil and moisture conservation through various World Bank assisted projects spread over 11 Indian states, including Andhra Pradesh, Maharashtra, Karnataka, Madhya Pradesh and Uttar Pradesh. Central Research Institute for Dryland Agriculture, Hyderabad; Pujabrao Krishi Vidyapeeth University, Akola, University of Agricultural Sciences, Bangalore, International Crops Research Institute for Semi Arid Tropics (ICRISAT), Hyderabad (vide Lodha 1998), Central Soil Salinity Research Institute, Karnal, and several other state funded organizations have since been involved in vetiver based environmental conservation efforts. Lately, some scattered efforts have been initiated for pollution mitigation of soil and water contaminated with heavy metals. However, in its homeland vetiver still remains the choice of industrialists for its valuable root oil, despite having potential for development of technologies for its multifarious environmental applications.

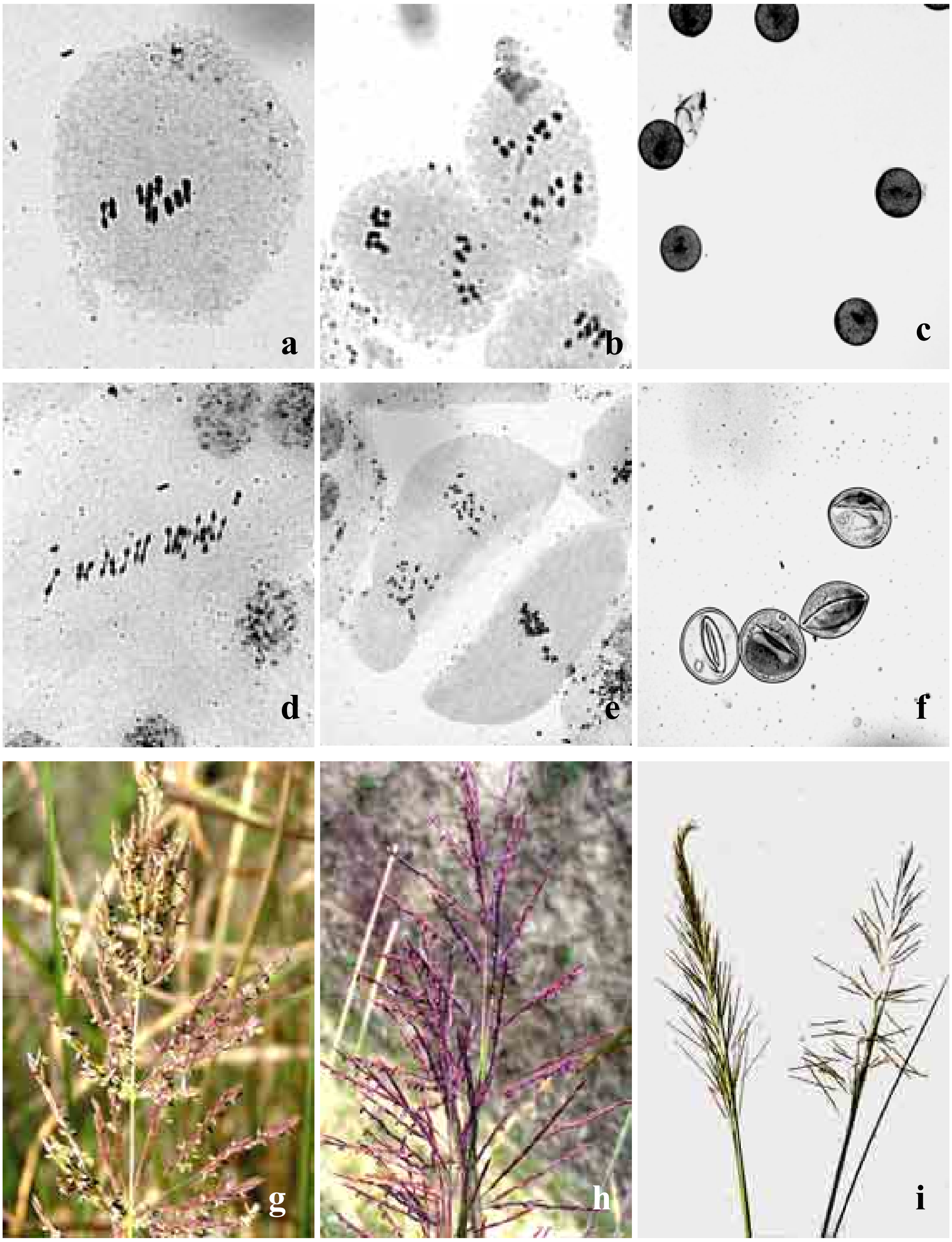

Figure 1: Meiotic, pollen, stigma and inflorescence characteristics in the diploid and autotetraploid Vetiver. a-f. meiotic metaphase, anaphase I and pollen fertility (a-c in diploid and d-f in tetraploid) – note empty sterile pollen in tetraploid; g-h. showing stigmatic diversity (g-white and h-magenta color feathery stigma), i. Inflorescence features in the diploid (left) and tetraploid (right), note lax inflorescence in the tetraploid with reduced number of florets.

5. INDUSTRIAL *VS* ENVIRONMENTAL APPLICATIONS: PROSPECTS AND PROMISES

As stated above Vetiver has two distinct applications: (i) for its root essential oil for perfumery industry for which we need genotypes that produce high concentration and superior quality of essential oil in their roots, and (ii) for multifarious environmental applications, including mitigation of carbon emissions for which we need plant types that produce (a) low oil / virtually no oil in its roots that works as a deterrent to local root diggers, (b) fast growing ideal root physiography suiting to desired application. Lavania S (2003) outlined root ideotype features commensurate with specific applications. Keeping in fitness with 'root-ideotype' following specifications are worth considering for development of specific genotypes for given applications.

(a) Essential Oil: Smooth – thick vertically growing roots with minimum branching, well developed phloem

(b) Land / Slope Stabilization / Bioengineering: Profusely branching, spreading type with least essential oil

(c) Water and Soil Reclamation: High absorption potential for soluble N, P, nitrates and pesticidal residues

(d) Soil and Water Detoxification and Pollution Mitigation: High absorption potential and tolerance to heavy metals

(e) Management of Waterlogged areas: Spongy roots with schizogenous cortex

(f) Carbon sequestration: Deep penetrating faster growing roots with low essential oil and thick vascular cylinder and suberised epiblema

Vetiver in India is endowed with tremendous diversity. Its seed forming ability unique only to north Indian vetiver opens opportunity to realize designer genotypes suitable for two alternative applications by genetic and genomic manipulations to realize specific plant or root ideotype suiting to specific applications. It is also possible to genetically manipulate reproductive system through ploidy intervention to realize non-invasive low-seed characteristics in seed forming type. Efforts in this direction are under way in author's laboratory. It is observed that the autotetraploids developed in vetiver evince high pollen sterility on account of disturbed meiosis (Figure 1) and low seed set with hardly 8-10% germination (Lavania *et al.* 2006) . Further if triploidy could be realized by intercrossing between the tetraploid stock and desired diploid genotype it may be highly rewarding because the triploids are expected to be almost fully sterile combined with robust plant habit (Lavania and Kumar 1988) – as commonly observed in other species (Riddle *et al.* 2006). Exomorphological markers such color and orientation of stigma (white –to- yellow –to-magenta / feathery, straight to inclined orientation), colour of glumes (greenish to pink), colour of leaf sheath and rachis (green, yellow and pink) could be used as valuable indicators to isolate triploid hybrid plant types.

6. CONCLUSIONS

With tremendous progress made in development of Vetiver system ecotechnology, it is high time that due emphasis is laid on development of designer genotypes suiting to specific applications of vetiver system. India being the home of vetiver is the only country where profuse seed formation takes in vetiver in its natural habitats. Seed grown progenies offer huge opportunities to tap the vetiver diversity to isolate plant genotypes suiting to specific applications. The genotypes so selected could be made to have noninvasive features with no seed formation to meet international obligations by changing them into triploids through tetraploid x diploid intercrossing.

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